REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. REPORT DATE *(DD-MM-YYYY)*	2. REPORT TYPE	3. DATES COVERED *(From - To)*
02/18/201403/21/2014	Interim Research Performance Report (Monthly)	February 1, 2014 - February 28, 2014

4. TITLE AND SUBTITLE
Expeditionary Light Armor Seeding Development

5a. CONTRACT NUMBER

5b. GRANT NUMBER
N00014-13-1-0219

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)
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5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
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OFFICE OF THE VICE PROVOST FOR RESEARCH
220 HULLIHEN HALL
NEWARK, DE 19716-0099

8. PERFORMING ORGANIZATION REPORT NUMBER
MONTHLY-11

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Office of Naval Research
875 North Randolph Street
Arlington, VA 22203-1995

10. SPONSOR/MONITOR'S ACRONYM(S)
ONR

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION / AVAILABILITY STATEMENT
Approved for Public Release; distribution is Unlimited.

13. SUPPLEMENTARY NOTES

14. ABSTRACT
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-In simulation the adhesive layer improves the ballistic efficiency of the target, experimental tests will confirm or deny this
-A step ladder seam design was designed and tested, results are positive
-Monolithic Aluminum base curve was re ran at 0.2 SPH and compared to ARL data, material properties may need to be adjusted

15. SUBJECT TERMS
Adhesive Layer Effect, .30cal AP M2 Projectile, 762x39 PS Projectile, SPH, Aluminum 5083, SiC, DoP Expeminets, AutoDyn Sin

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
UU					Shridhar Yarlagadda
a. REPORT	b. ABSTRACT	c. THIS PAGE	UU	13	19b. TELEPHONE NUMBER *(include area code)*
					302-831-4941

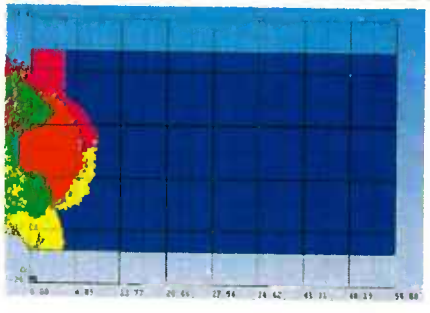
PROGRESS REPORT

Nicole A. Cicchetti, Bazle Z. (Gama) Haque,
Shridhar Yarlagadda

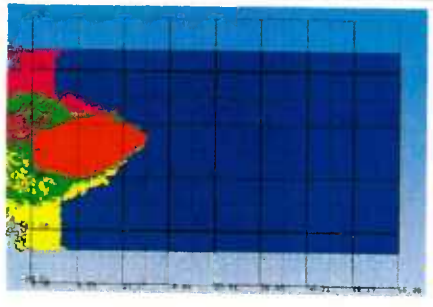
MODELING AND SIMULATION OF CERAMIC ARRAYS TO IMPROVE BALLISTIC PERFORMANCE

EFFECT OF TILE THICKNESS ON DOP AT 850m/s GAP SIZE 0.508mm

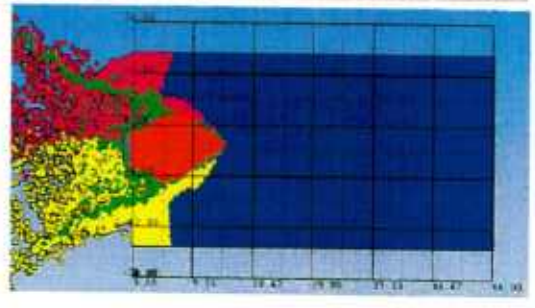
No Gap, DOP 10.33 mm



5 mm Thick, DOP 17.19 mm

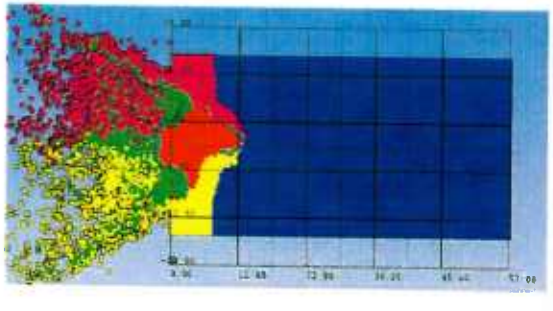


6 mm Thick, DOP 14.00 mm

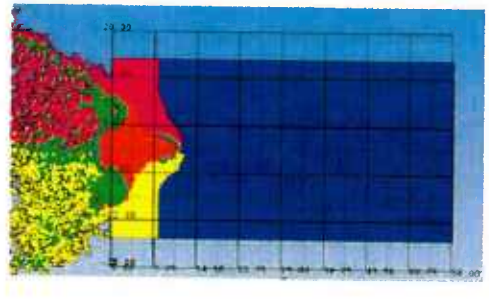


Depth of Penetration on Baseline Tiles and Modified Tiles at 850 m/s, Gap Size 0.508 mm		
Gap Size t_{gap} (mm)	Tile Thickness H_c (mm)	Depth of Penetration d_p (mm)
Baseline (0)	5	10.3
0.508	5	17.2
0.508	6	14.0
0.508	7	11.4
0.508	8	10.8
0.508	9	9.8

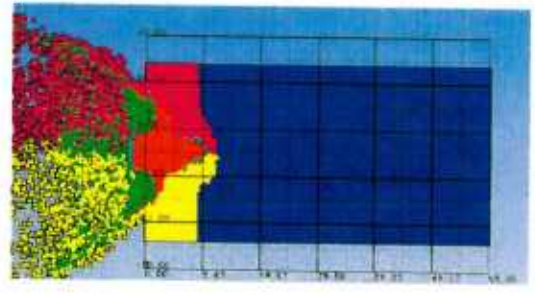
7 mm Thick, DOP 11.40 mm



8 mm Thick, DOP 10.80 mm

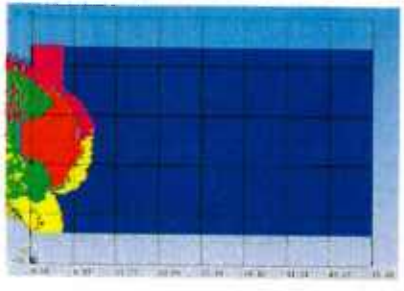


9 mm Thick, DOP 9.83 mm

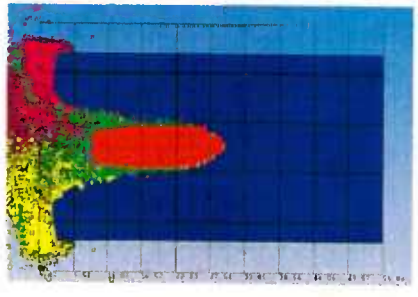


EFFECT OF TILE THICKNESS ON DOP AT 850m/s GAP SIZE 1.016mm

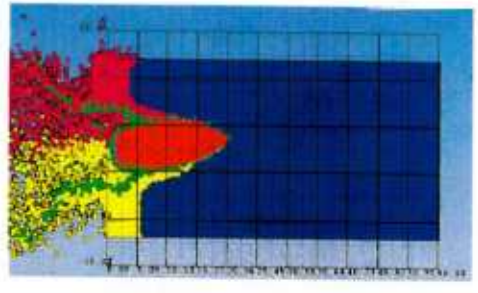
No Gap, DOP 10.33 mm



5 mm Thick, DOP 30.29 mm



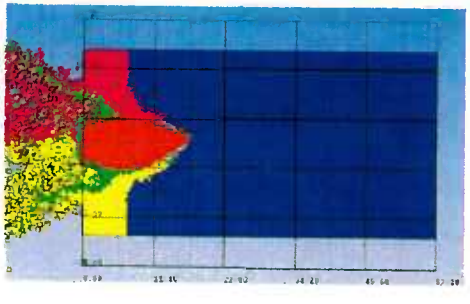
6 mm Thick, DOP 20.95 mm



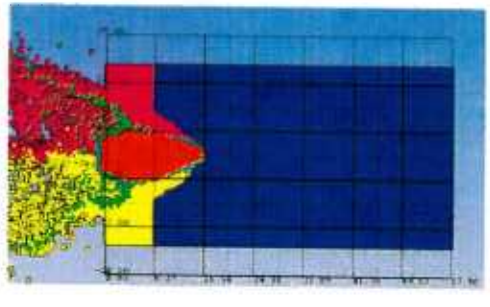
Depth of Penetration on Baseline Tiles and Modified Tiles at 850 m/s, Gap Size 1.061 mm

Gap Size t_{gap} (mm)	Tile Thickness H_c (mm)	Depth of Penetration d_p (mm)
Baseline (0)	5	10.3
1.016	5	30.3
1.016	6	21.0
1.016	7	16.8
1.016	8	16.6
1.016	9	14.8

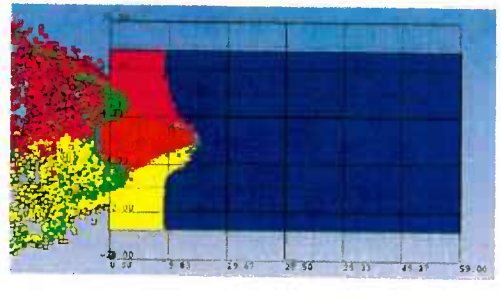
7 mm Thick, DOP 16.76 mm



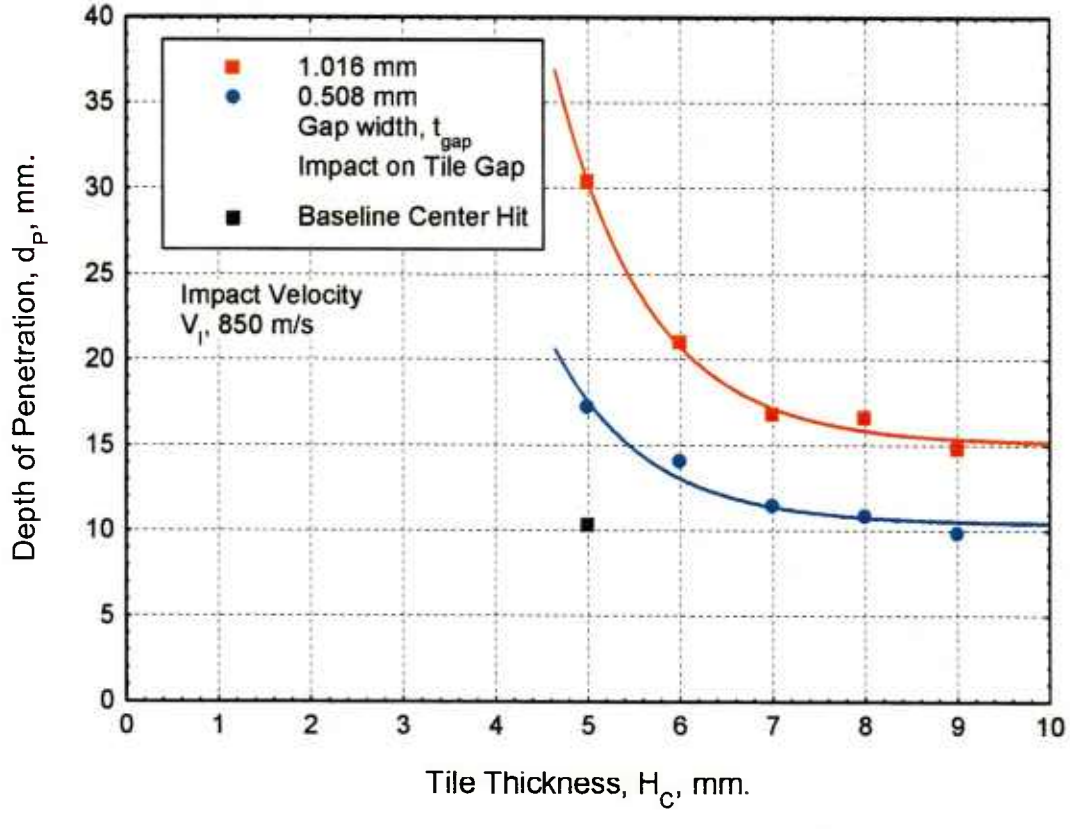
8 mm Thick, DOP 16.59 mm



9 mm Thick, DOP 14.77 mm

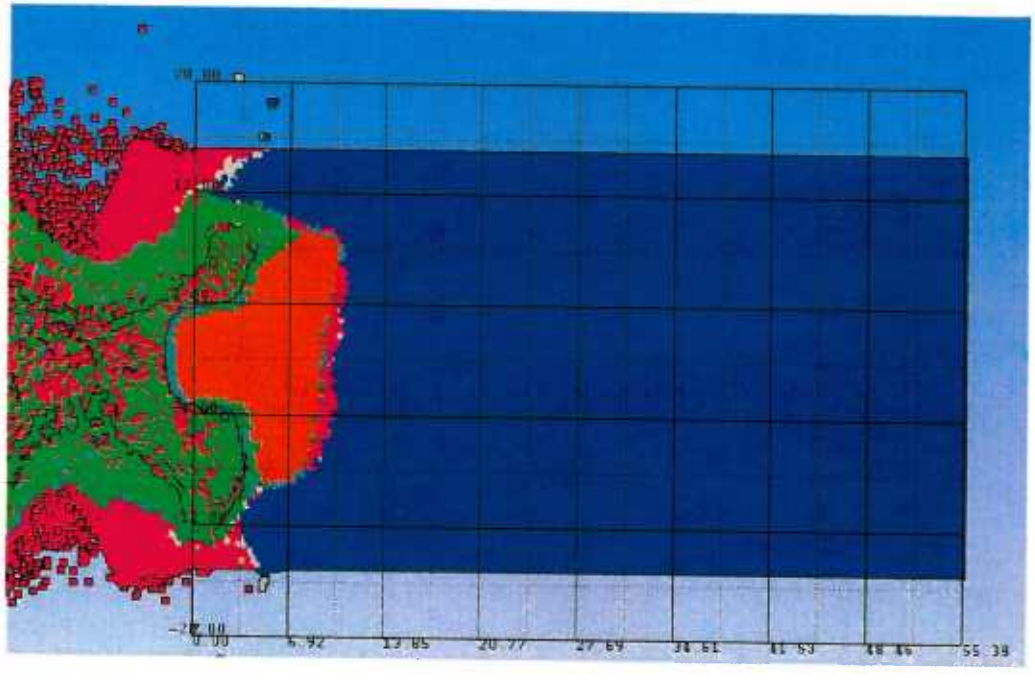


AUTODYN SIMULATION DOP VS TILE THICKNESS



- When the gap is held at 1.016 mm the baseline DOP of a center impacted tile cannot be effectively achieved
- A gap size of 0.508 mm allows the baseline to be achieved and gap size of 0.508 mm will be the gap size in use moving forward

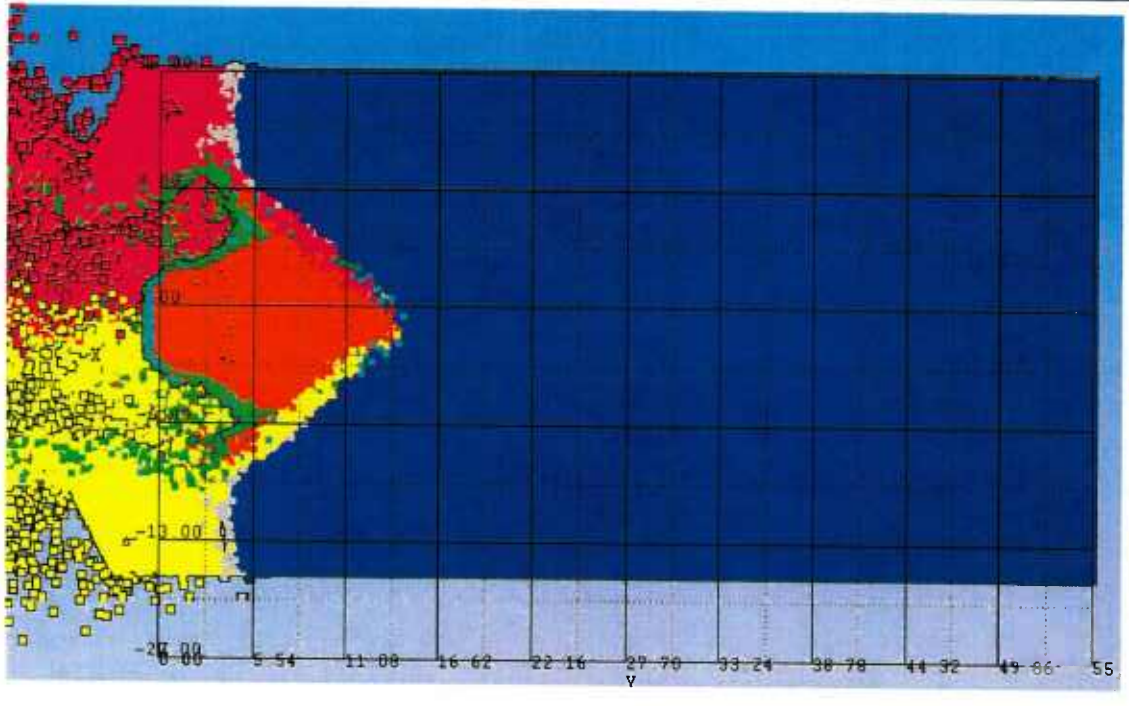
ADHESIVE LAYER EFFECT ON CENTER IMPACTED 5*mm* THICK TILE



Adhesive Layer DOP Compared to No Adhesive Layer DOP, Gap 0.508 mm	
Adhesive Layer DOP (mm)	Baseline Center Impact DOP (mm)
10.1	10.3

- An adhesive layer of Epoxy Resin was added in between the SiC tile and the Al backing
- The tile remained 5 mm thick

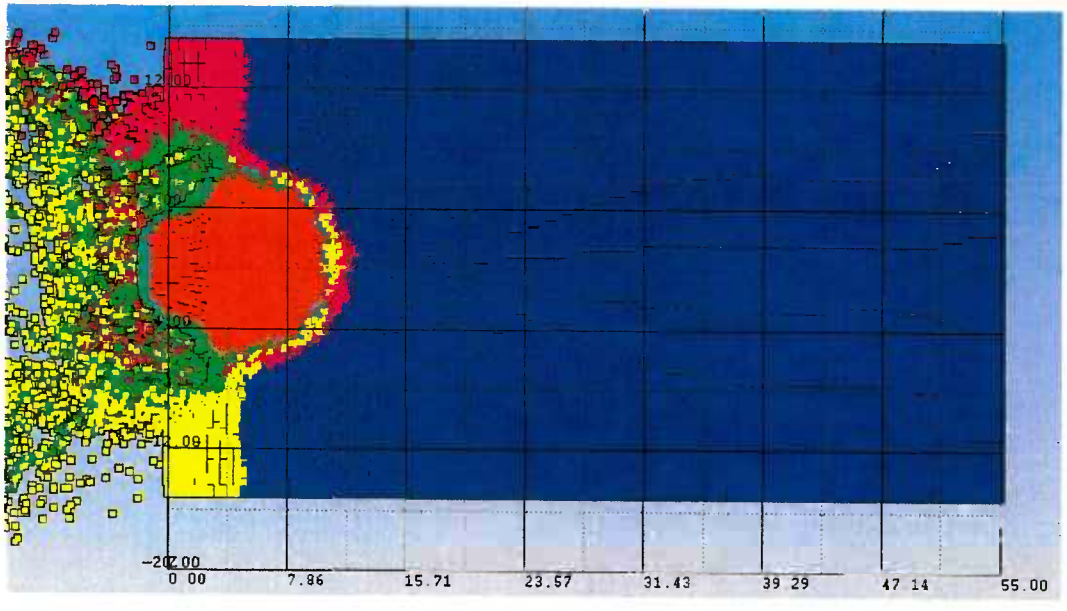
ADHESIVE LAYER EFFECT GAP SIZE 0.508*mm* 5*mm* THICK TILE



Adhesive Layer DOP Compared to 0.508 mm Gap with No Adhesive DOP	
Adhesive Layer DOP (mm)	**Tile Gap 0.508 mm with No Adhesive DOP (mm)**
13.9	17.2

- An adhesive layer of Epoxy Resin was added in between the SiC tile and the Al backing
- The tile remained 5 mm thick and the gap size at 0.508 mm to compare when no adhesive was added

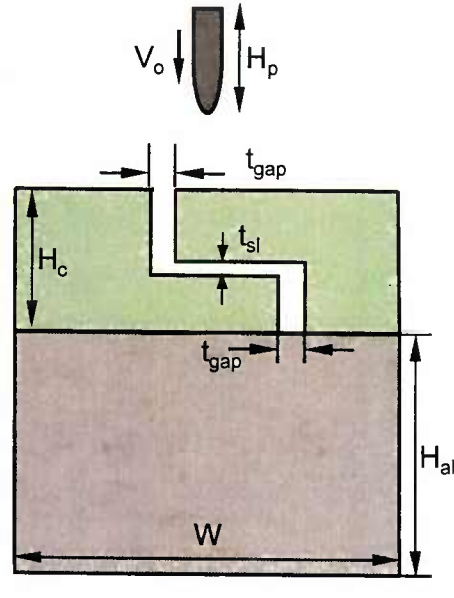
CENTER IMPACTED STEP LADDER



Step Ladder DOP Compared to Baseline Gap 0.508 mm DOP	
Step Ladder DOP (mm)	**No Step Ladder DOP (mm)**
11.8	17.2

- An Step Ladder was created at the seam according to the schematic at right
- The tile remained 5 mm thick and the gap size at 0.508 mm to compare to the baseline results

Part	
V_o	850 m/s
H_p	35.31 mm
t_{gap}	0.508 mm
H_c	5 mm
t_{sl}	0.2 mm
H_{al}	50 mm
W	30 mm

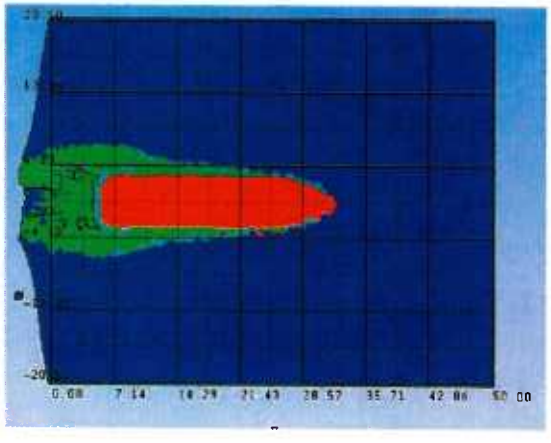


- Earlier DoP Simulations have been performed using SPH size 0.40-mm
- Recent DoP Simulations of (i) Step-Ladder Tiles and (ii) Center Impact with Adhesive Layers have been conducted with SPH size 0.20-mm
- This is why we reran the DoP of Aluminum with SPH size 0.20-mm to be consistent

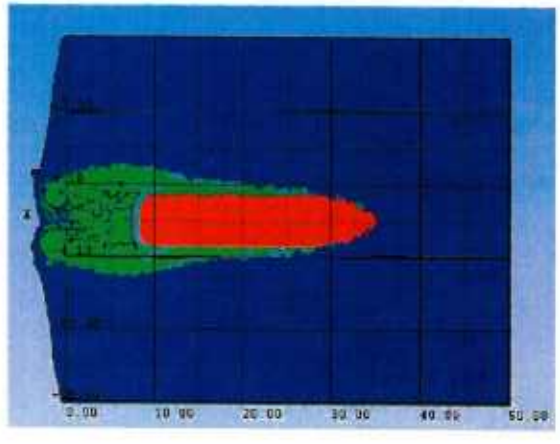
DOP SIMULATION OF ALUMINUM TARGETS WITH $0.20mm$ SPH SIZE

MONOLITHIC Al5083 DOP CALIBRATION AT SPH SIZE 0.2

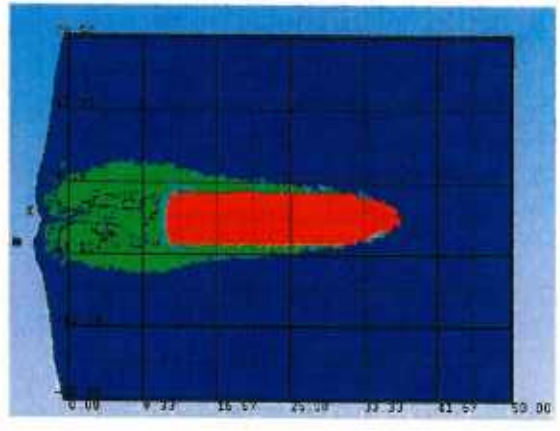
700 m/s



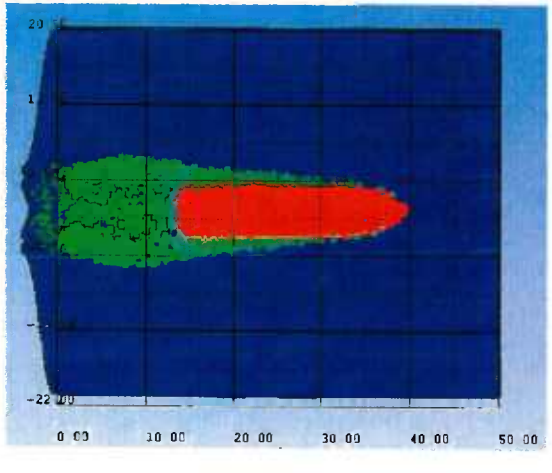
750 m/s



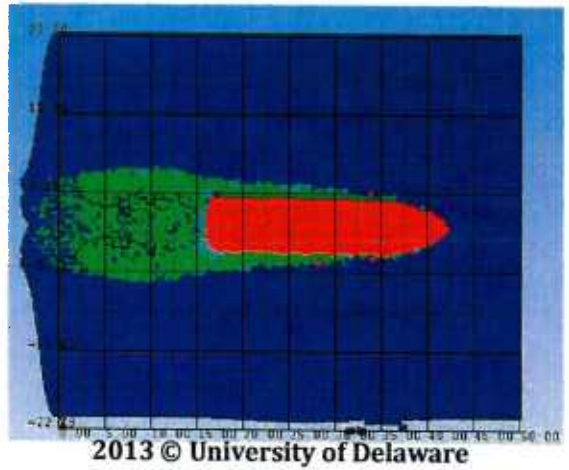
800 m/s



850 m/s



900 m/s



Monolithic Al5083 DOP	
Velocity (m/s)	DOP (mm)
700	32.1
750	35.0
800	37.5
850	40.0
900	42.5

ARL MONOLITHIC AL5083 DOP

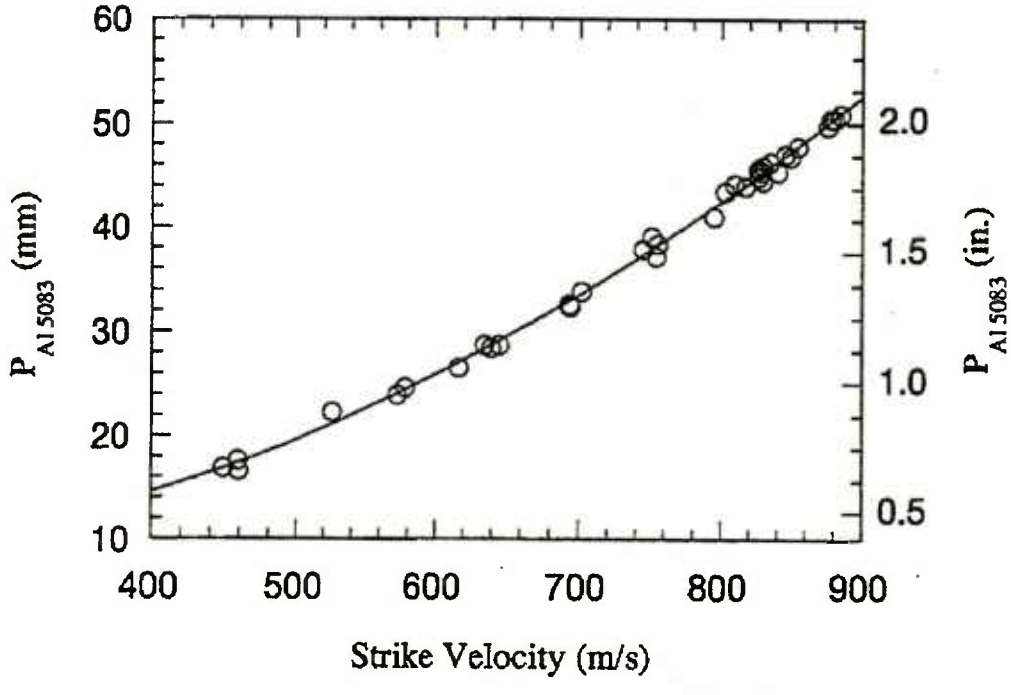


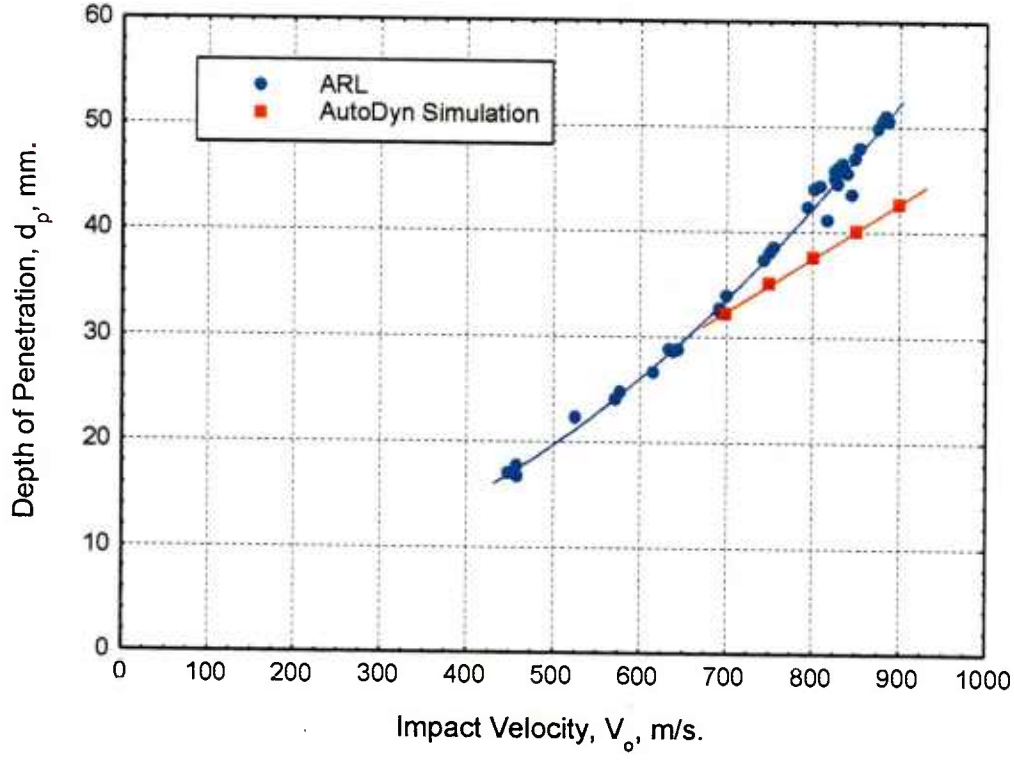
Figure 2. Penetration Into Monolithic Aluminum (Al 5083) vs. Strike Velocity.

- **ARL ranged from 400 to 900 m/s, we will only be running experimental tests on 700 to 900.**

[a] Data point disregarded, due to excessive pitch/yaw.

Moynihan, Thomas J., Shun-Chin Chou, and Audrey L. Mihalcin. *Application of the Depth-of-Penetration Test Methodology to Characterize Ceramics for Personnel Protection.* Rep. Aberdeen Proving Ground, MD: Army Research Laboratory, April 2000. Print.

AUTODYN AND ARL DOP VS IMPACT VELOCITY



- Simulation results do not show the same trend as the ARL experimental data
- Simulations will be extended over a larger range of Impact Velocities
- Material properties may be edited if the properties do not match the material properties used in the ARL experiments

SUMMARY

- The effect of tile thickness at varying gap sizes was explored, finding that a center impact DOP can on be achieved if at a gap size of 0.508 mm
- In simulation the adhesive layer improves the ballistic efficiency of the target, experimental tests will confirm or deny this
- A step ladder seam design was designed and tested, results are positive
- Monolithic Aluminum base curve was re ran at 0.2 SPH and compared to ARL data, material properties may need to be adjusted